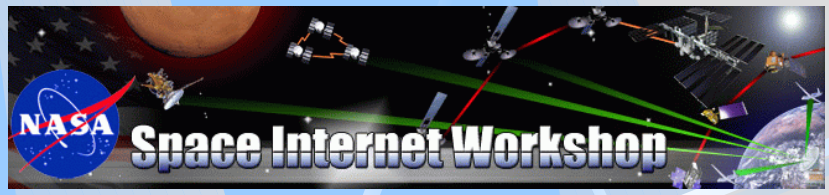

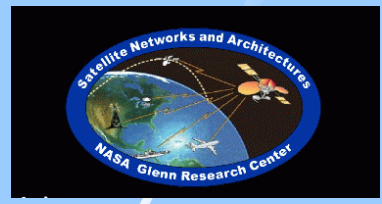

Mobile Ad hoc Networks for Space and Surface Systems

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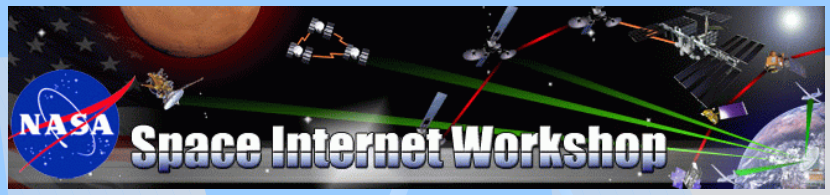
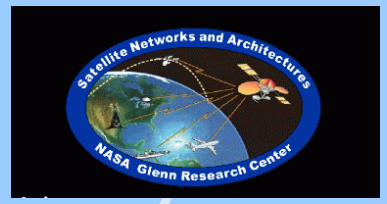
NASA Glenn Research Center

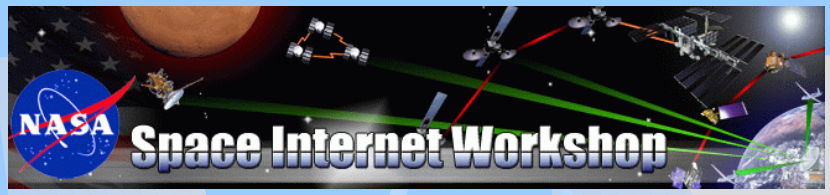
June 5, 2003

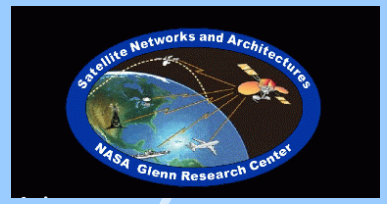




Introduction

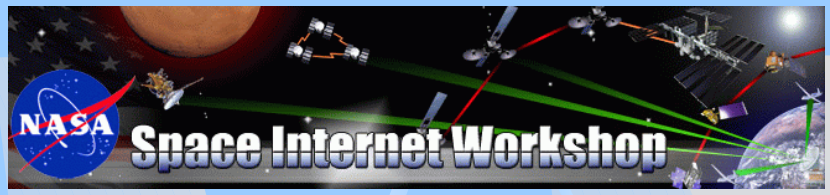
- NASA's Wireless Communication System
  - Fixed infrastructure – SGLS, STDN, DSN
    - Command uplink with downlink repeat back
    - Telemetry and mission data downlink
  - Optimized for power, mass and volume
  - Protocols mostly based on USB/CCSDS
  - Future goal - total communications integration
    - New antennas, radios and protocols
    - Fixed versus Ad hoc infrastructure ?

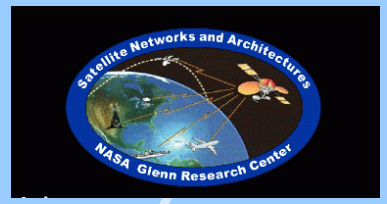




Fixed versus Ad Hoc

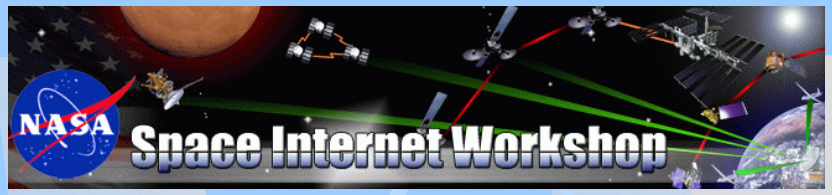
- Traditional fixed wireless networks
  - Use Base Station or Access Point
  - Mobile nodes within range
    - Cellular phone networks – AMPS CDMA GSM
    - LAN networks – 802.11a 802.11b 802.11g
- Ad Hoc wireless networks
  - Use Mobile nodes and Gateway for reach back
  - IETF – Mobile Ad hoc NETworks or MANET

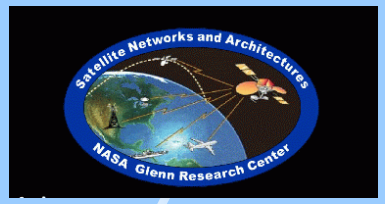




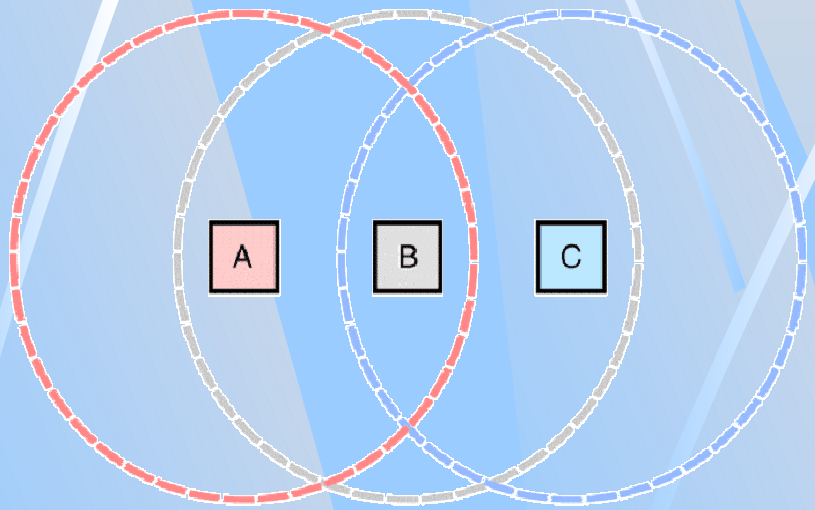
Mobile Ad hoc NETworks

- When fixed infrastructure solution is unavailable
  - Energy constraints
  - Destroyed or damaged
  - At maximum capacity
  - Costs too much for service
  - Issues with access, trust or registration
- Autonomous system of mobile routers
  - Free to move randomly – topology change
  - Stand alone network or with reach back





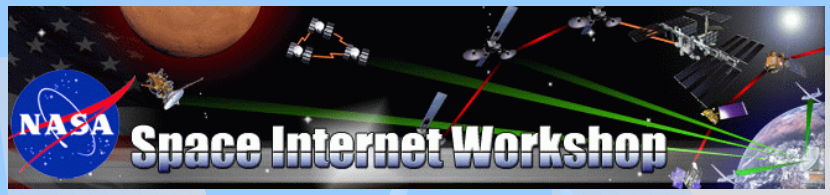
MANET Example

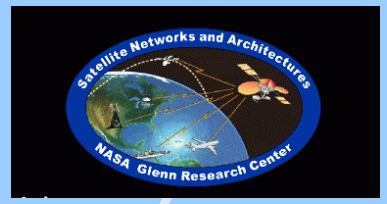


Example: p=1/R^4 for 2 meters

- A-C 256 mWatts
- A-B B-C 16 + 16 = 32 mWatts

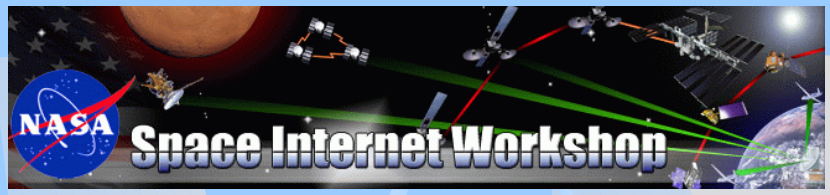
- A and B within range
- B and C within range
- B is router for A and C
  - As nodes move - need to find another route
- Shortest path solution is based on cost calculation
  - Bellman-Ford
  - Dijkstra algorithm
- Complexity grows with more nodes

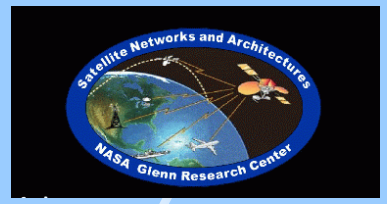




MANET Protocol Types

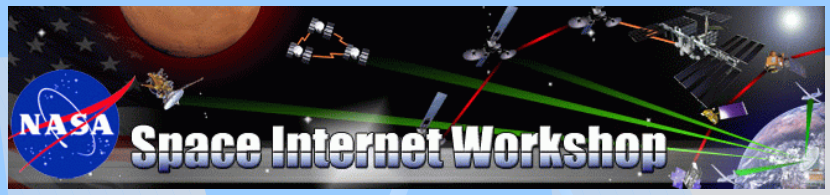
- Pro-active – Timer driven
  - Optimized Link State (OLSR)
  - Topology Broadcast based on Reverse-Path Forwarding routing protocol (TBRPF)
- Reactive – Interrupt driven
  - Ad hoc On Demand distance Vector routing protocol (AODV)
  - Dynamic Source Routing protocol (DSR)

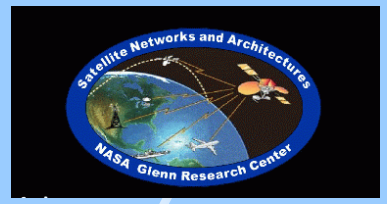




MANET Assumptions

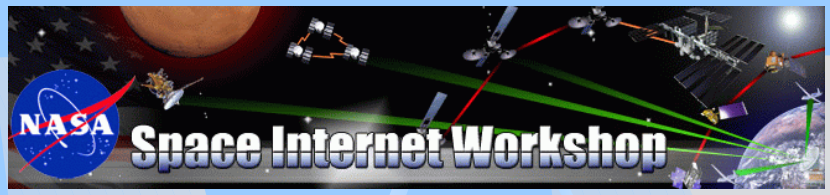
- Nodes work together
  - Share standard protocol
  - No interference – play together fairly
- No duplicate (IP) addresses
  - Handled outside the MANET protocol
- Share same wireless channel
  - Use omni directional antenna

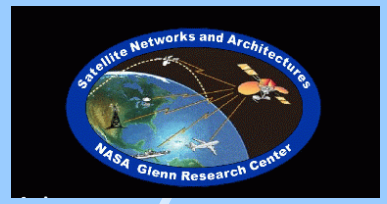




MANET Networks

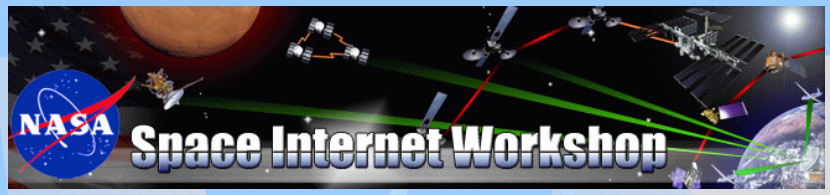
- Characteristics
  - Dynamic topologies
  - Bandwidth and energy constraints
  - Limited physical security
- Metrics
  - Size of network – number of nodes
  - Network connectivity – average degree per node
  - Topology rate of change
  - Link capacity

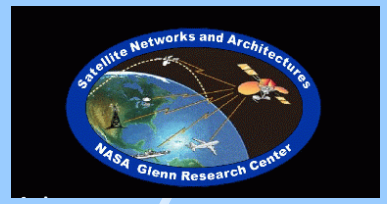




MANET Metrics

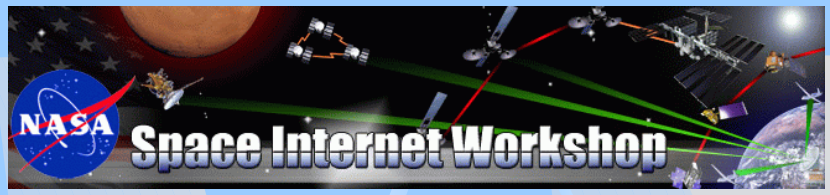
- Data throughput and delay
- Route acquisition time
- Percent out of order deliver
- Efficiency
  - Number of extra hops compared to optimal
  - Protocol overhead
    - Amount of control overhead compared to data

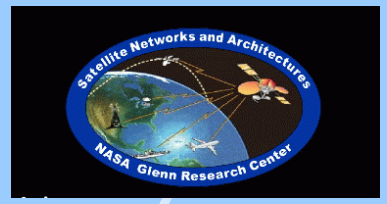




802.11 MAC

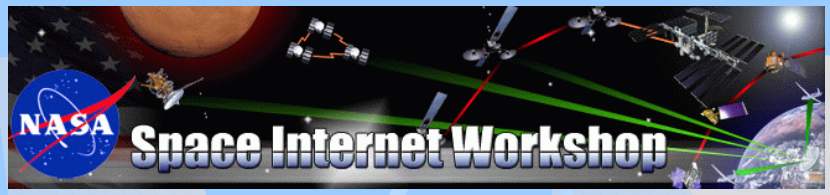
- Two modes of operation
  - Point to multipoint – Access point mode
    - 2048 total nodes – 20 recommended
  - Point to point – Ad hoc mode
    - Unlimited nodes – 10 recommended
- 2.4 or 5 Ghz frequency bands
- 300 meters range – hidden node problem
- 128 bit cipher key – has security flaw
- No space qualified 802.11 device available

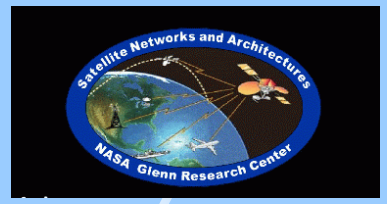




Satellite Configurations

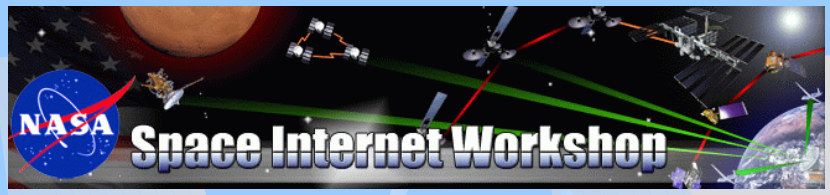
- Stand alone Satellites
  - Store and dump operations
    - Example: IKONS building more ground stations
- Distributed Spacecraft Constellations
  - Use crosslink communications to share information
    - Example: Iridium, GPS
- Formation Flying Missions
  - Require crosslink communications to maintain position
    - Example: Techsat 21, MAXIM

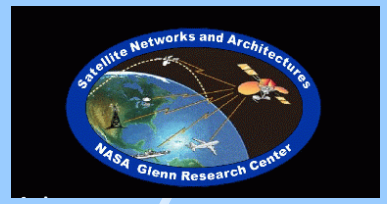




Distributed Spacecraft Constellations

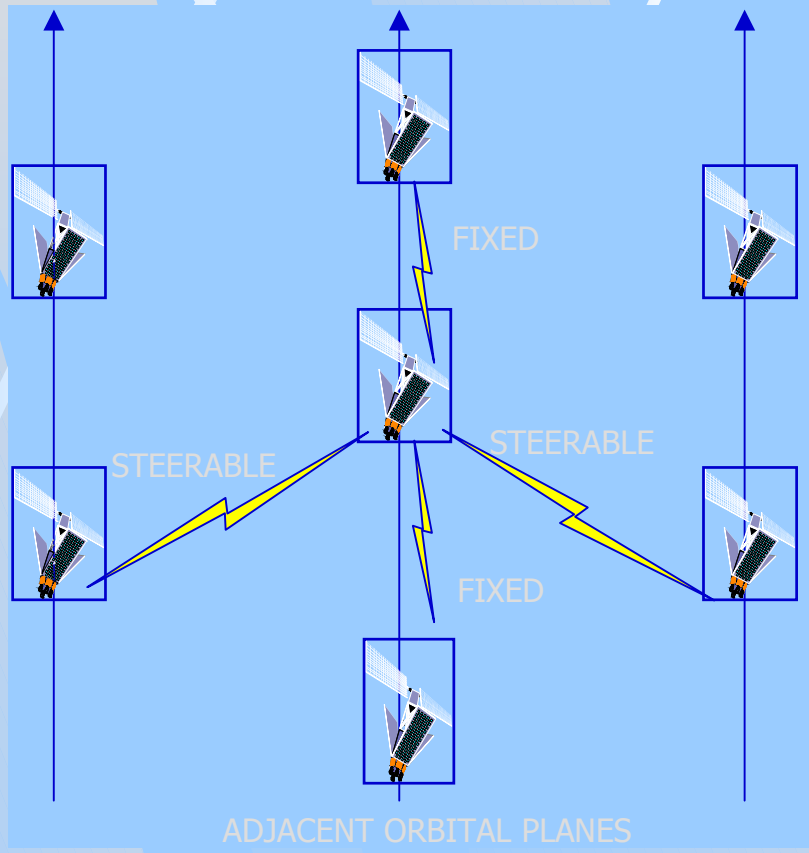
- Orbits around Earth or other planetary bodies
- Rely on ground segment
  - Navigation
  - Command and Control
  - Orbital corrections
- Example: Iridium
  - Six orbital planes
  - Eleven satellites in each plane



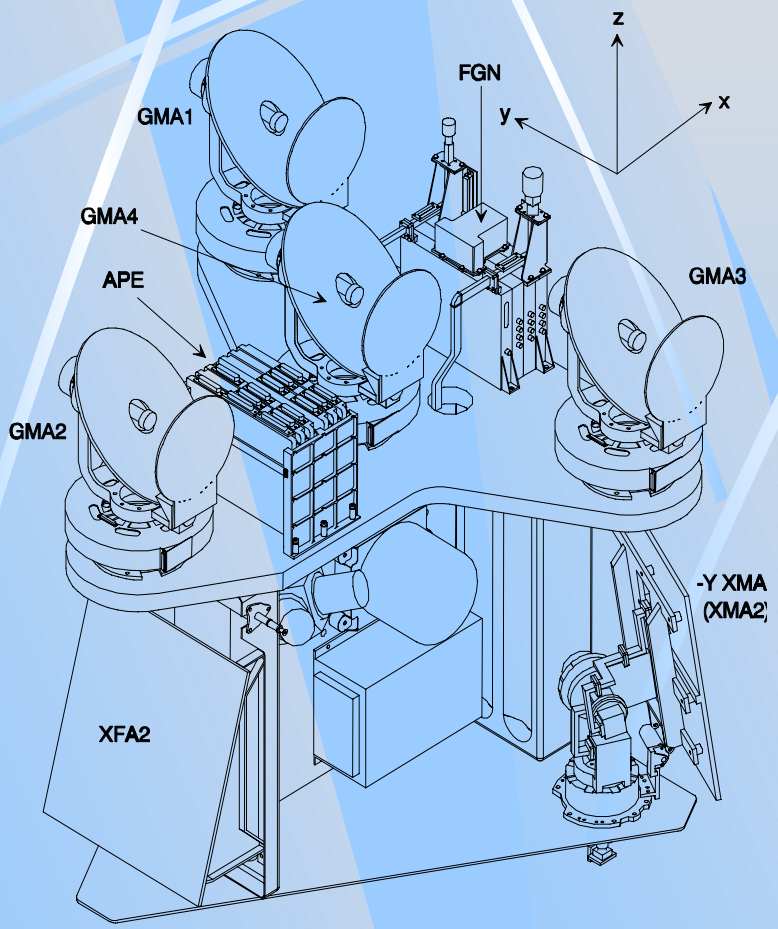


Iridium Orbital Planes

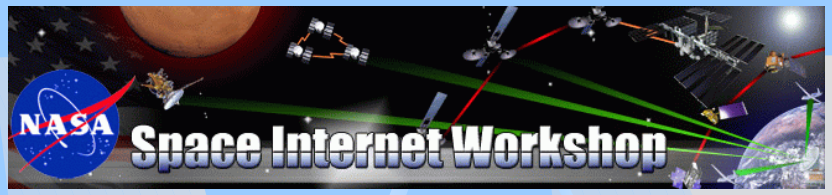
- Iridium satellites have almost zero relative motion between the same and adjacent orbital planes
  - Minimal Doppler shift
  - Constant communications
- At orbital boundary, on coming satellites have large relative motion between satellites
  - Large Doppler shift
  - Intermittent communications

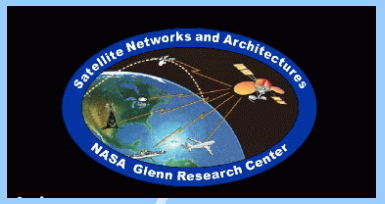


Iridium Crosslinks

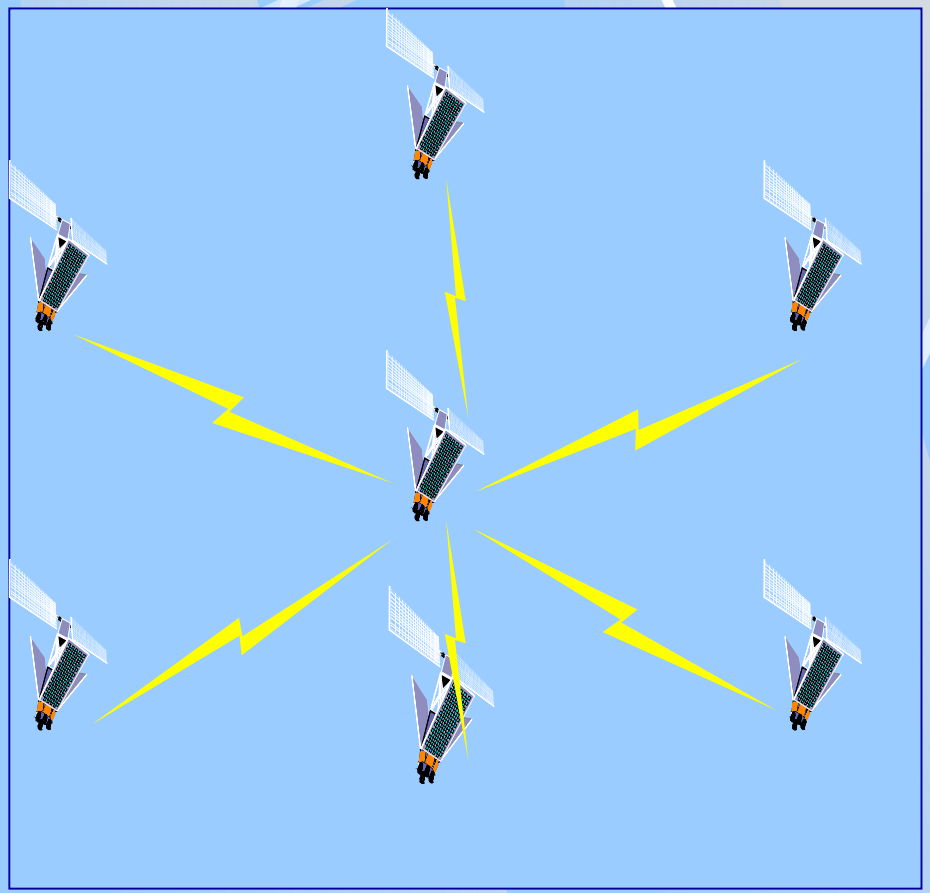


- Fore & Aft fixed beams for satellites in same orbital plane
- Steerable, gimbaled beam on each side for linking with adjacent orbital planes
- Each beam utilizes independent antenna & transmitter hardware

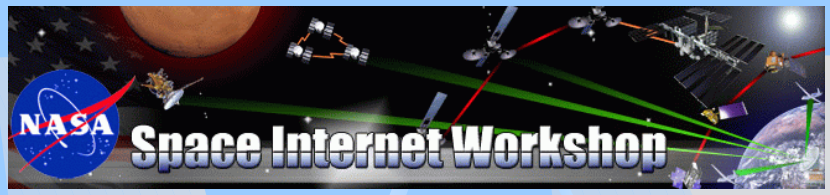


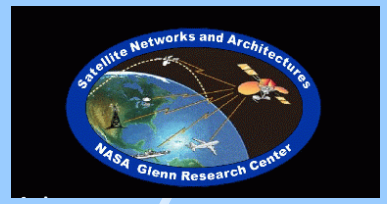


GPS Crosslink System



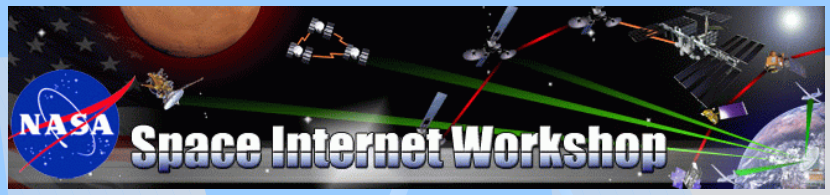
- UHF TDMA Frequency Hopped Spread Spectrum Communications System
- Provides Inter-Satellite RF Link to Support AutoNav Function
  - Makes Accurate (<.5 meter) Dual Frequency Range Measurements Between Satellites
- Broadcast architecture reaches all line-of-sight satellites simultaneously
- Each satellite transmits in its assigned time interval

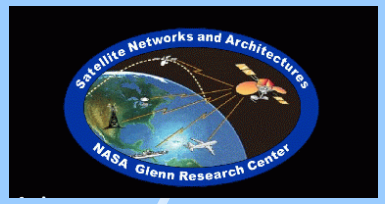




Formation Flying Missions

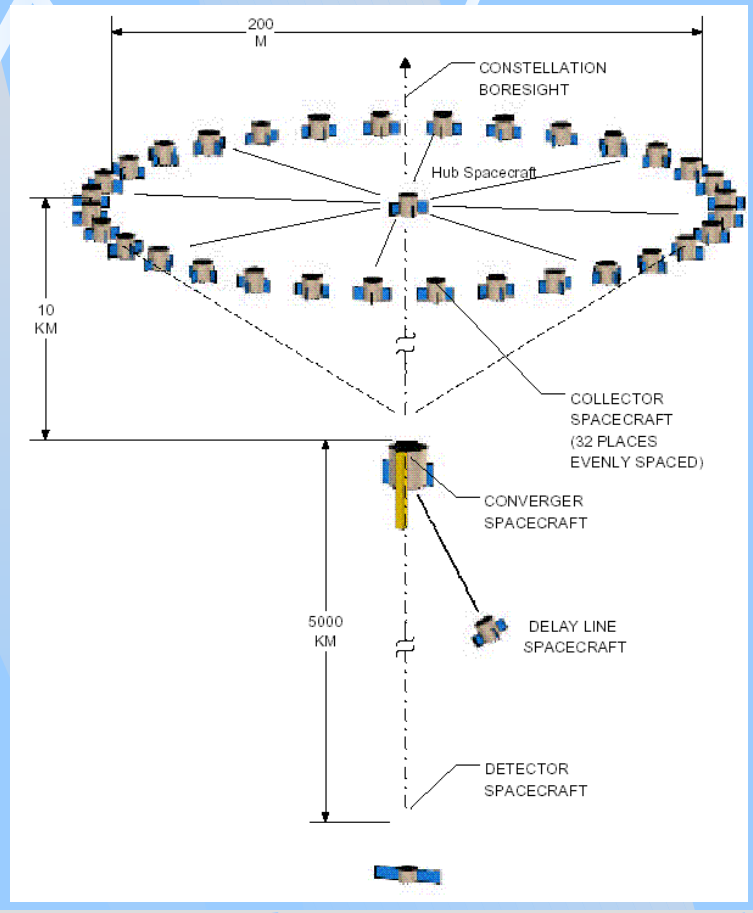
- Involve two or more satellites
  - Maintain position with respect to each other
- Orbits around Sun or other planetary bodies
- Rely on ground segment
  - Navigation
  - Command and Control
- Example: MAXIM
  - Micro-Arcsecond X-ray Imaging Mission

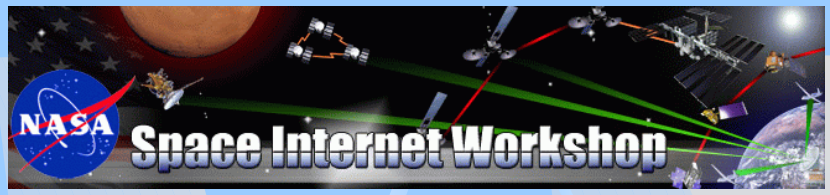


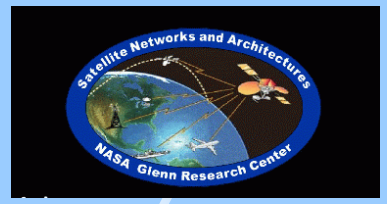


MAXIM Formation

- MAXIM satellites have zero relative motion between satellites
  - No Doppler shift
  - Constant communications
- Maintain formation by sharing navigation and command information in real time by crosslinks

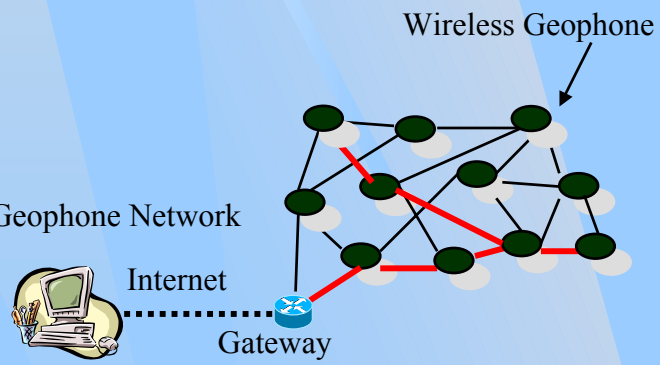


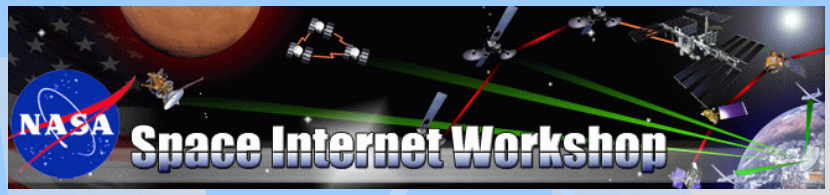


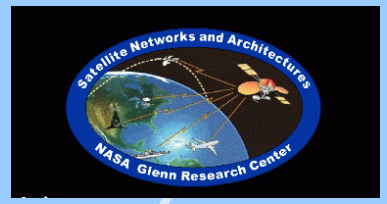


Proximity Networks

- Collection of data sensors with communications services
  - Sense the environment
  - Process the data
  - Send information through network to end users
- Example: Geophones
  - Low frequency microphone
  - Data storage device
  - Wireless communications

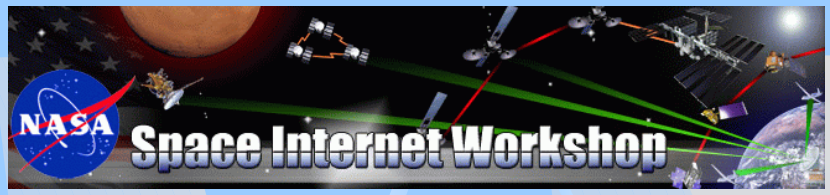


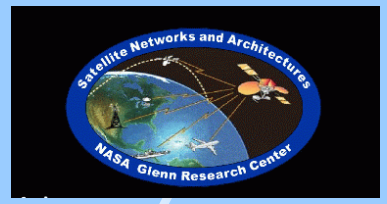




Summary

- MANET
  - Focused on router functions for mobile nodes
  - Moving in random and unpredictable manner
  - Use when fixed infrastructure solution is unavailable
  - Issue - need to reach outside router layer to help resolve complexity issues
- Satellites have predictable orbits
  - Fixed infrastructure is optimal configuration
- Proximity networks
  - Use MANET technology to address energy constraints





Thank-you

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